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MEMOIRS OF THE HOURGLASS CRUISES

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PART I

THE ROCK SHRIMP, *SICYONIA BREVIROSTRIS* STIMPSON, 1871 (DECAPODA, PENAEIDAE)

By

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ABSTRACT

Sicyonia brevirostris were collected monthly from the west Florida shelf during Project Hourglass. A total of 973 rock shrimp were weighed, measured, sexed, and examined for morphological variation. Ovaries of 463 females were removed and classified as undeveloped, early developing, developed, ripe, and spent, for study of the reproductive cycle.

Ovarian development is ontogenetic in small females, but seasonal in larger shrimp. Spawning apparently occurred throughout the year with a peak between October and February. Daily photoperiod length possibly initiated spawning. Recruitment of smallest juveniles occurred in March, May through July, and November, but slightly larger juveniles occurred in all months except December, further indicating year-round spawning.

Statistical analysis indicated the sex ratio was not significantly different from 1:1, but females were more abundant in larger size categories than males. Minimum size at onset of sexual maturity was estimated as 9.0 mm carapace length (CL) for males and 13.0 mm CL for females.

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S. brevirostris was largely confined to middle portions of the shelf and was most abundant at 37 m stations. Bathymetric distribution seems related to substrate and hydrographic properties of this zone. Population density fluctuated seasonally and was greatest from July through November.

$\log \hat{Y} = -3.2192 + 3.1279 \log X$ expresses the carapace length (X) - total weight (Y) relationship for both sexes combined. Equations converting carapace length (X) and total length (Y) are: males, $\hat{Y} = 3.7783X$, $X = 0.2644Y$; females, $\hat{Y} = 4.4503 + 3.4562X$, $\hat{X} = -0.9152 + 0.2847Y$. Heading of fresh rock shrimp results in a 40% weight loss; shelling of tails causes an additional loss of 16% from whole weight and a 27% loss from tail weight.

Sicyonia brevirostris is a generalized carnivore, feeding primarily on mollusks and crustaceans. Feeding activity is nocturnal and occurs yearlong.

No economically important concentrations of rock shrimp were found in the study area, but populations with apparent economic potential have been reported off Cape St. George, Florida, Cape Canaveral, Florida and Isla Contoy, Mexico.

INTRODUCTION

The rock shrimp, *Sicyonia brevirostris*, is the largest and possibly most abundant western Atlantic member of the genus and is, at times, taken in commercial quantities.

Except for ecological studies by Lunz (1957), development studies by Cook and Murphy (1965), and various taxonomic treatments, little is known about the biology of *S. brevirostris*. This study is an ecological analysis of rock shrimp collected in the eastern Gulf of Mexico during Project Hourglass, and includes a redescription and synthesis of existing knowledge on the species. New data are presented on the reproduction, diet, distribution, population dynamics, and morphological variation of the species. Information contained herein should serve as a basis for future research and management of rock shrimp resources.

ACKNOWLEDGMENTS

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METHODS AND MATERIALS

Collection. *Sicyonia brevirostris* were collected by the Marine Research Laboratory, Florida Department of Natural Resources, during Project Hourglass, a 28-month systematic sampling program on the west Florida shelf (Joyce and Williams, 1969). Ten fisheries stations (A, B, C, D, E, I, J, K, L, M), five along each of two transects off Tampa Bay and Sanibel Island (Figure 1, Table

1), were sampled monthly from August 1965 through November 1967. All stations were sampled at night (regular cruises); Stations B, C, and D were also visited during daylight hours (post-cruises). Supplementary cruises were made in July 1966 and January 1967.



Figure 1. Hourglass cruise pattern and station locations.

During regular and post-cruises, 15 min dredge and 30 min (bottom time) trynet tows were made for benthic organisms. The dredge was a box-type, 13 x 36 x 30 in., lined with 3/4 x 1 1/2 in. metal screening. The trynet used for the first 13 months was a standard 20 ft (distance between doors) flat trynet with 2 in. stretched mesh. For the remainder of the program, collections were made with a standard 20 ft balloon trynet of 2 in. stretched mesh. On supplementary cruises, a 45 ft balloon otter trawl was employed in tows of 30 min duration.

Salinity, temperature, and Secchi disk readings are listed by Joyce and Williams (1969), along with techniques used in collecting and analyzing hydrographic data. In this analysis, only Secchi disk readings made on virtually clear days were included in calculations used to distinguish water masses.

TABLE 1. LOCATION OF HOURGLASS FISHERIES STATIONS.

Station	Location*		Established	Approximate Nautical Miles Offshore*
	Lat.	Long.	Depth Meters	
A	27°35'N	82°50'W	6	04-due W of Egmont Key
B	27°37'N	83°07'W	18	19-due W of Egmont Key
C	27°37'N	83°28'W	37	38-due W of Egmont Key
D	27°37'N	83°58'W	55	65-due W of Egmont Key
E	27°37'N	84°13'W	73	78-due W of Egmont Key
I	26°24'N	82°06'W	6	04-due W of Sanibel Island Light
J	26°24'N	82°28'W	18	24-due W of Sanibel Island Light
K	26°24'N	82°58'W	37	51-due W of Sanibel Island Light
L	26°24'N	83°22'W	55	73-due W of Sanibel Island Light
M	26°24'N	83°43'W	73	92-due W of Sanibel Island Light

*U. S. Coast and Geodetic Chart 1003 dated June, 1966.

Material Examined. A total of 973 *Sicyonia brevirostris* were collected during Project Hourglass; most were accessioned into our Invertebrate Reference Collection (FSBC I). Over 94% (921) of the specimens were found in trawl samples (Table 2), and the remainder in dredge hauls. Little variation in catches was observed between the 20 ft balloon and flat trynets. The 45 ft otter trawl yielded only slightly higher catches than the 20 ft nets. A small quantity of additional material from other regions of the Gulf of Mexico and off the east coast of Florida, and one specimen from the Yale Peabody Museum (YPM 5070) from the eastern Pacific were examined.

Large shrimp were measured to the nearest 0.1 mm with vernier calipers, and very small individuals were measured with fine-point dividers. Carapace length (CL) from posterior margin of orbit to posterior border of carapace was used as a measure of shrimp size. Total length was not used as the standard measure because of distortion of preserved specimens and changes in length and elevation of the rostrum with size and sex. Most shrimp were weighed on a triple-beam balance to the nearest 0.01 g after removal of excess water with a paper towel; very small individuals were weighed on a Mettler H-5 balance.

TABLE 2a. NUMBERS OF SHRIMP IN TRAWL AND TRYNET CATCHES

Sicyonia brevirostris																															
1965	1966												1967												Tot						
	A	S	O	N	D	J	F	M	A	M	J	J	Jsp	A	S	O	N	D	J	Jsp	F	M	A	M		J	J	A	S	O	N
A																															0
B ₁				1	1		4	1			2			10																	19
B ₂																															0
C ₁																															258
C ₂																															12
D ₁																															154
D ₂																															20
E																															140
I																															1
J																															4
K	11																														231
L																															44
M																															38
TOT	11	0	6	14	11	13	10	42	20	3	27	62	132	30	79	31	62	20	40	32	9	9	12	8	10	19	33	26	82	68	921

TABLE 2b. NUMBERS OF SHRIMP IN DREDGE CATCHES

Sicyonia brevirostris																																					
Vls	1965												1966												1967												Tot
	A	S	O	N	D	J	F	M	A	M	J	J	Jsp	A	S	O	N	D	J	Jsp	F	M	A	M	J	J	A	S	O	N							
A																															0						
B ₁																															0						
B ₂																															0						
C ₁																			1												1						
C ₂																			3												5						
D ₁																															10						
D ₂																			1												1						
E																															2						
I																															0						
J																															9						
K																															14						
L																															7						
M																															3						
TOT	0	0	0	0	0	0	2	4	1	0	1	0	5	0	0	3	11	2	0	1	0	0	0	0	1	4	2	3	0	3	9	52					

*SCUBA collection.

Subscripts 1, 2 and sp represent regular, post and supplementary cruises.

Terminology of abdominal sculpture follows that developed for *Sicyonia* by Burkenroad (1934b). Figure 2 is a lateral view of an abdominal somite showing grooves and other sculpture. Nomenclature of thelycum and petasma follows Kubo (1949).

Reproduction. Ovaries of 463 *Sicyonia brevirostris* were examined to elucidate the reproductive cycle. Because of time restrictions and preservation methods, ovarian smears rather than histological preparations were used in assigning ovaries to developmental stages. Analysis of variance did not reveal a significant difference in mean oocyte diameters between anterior, middle, and posterior areas of the ovary. Therefore, the portion of the ovary from the first two abdominal somites was used exclusively. A smear was made of each excised segment of ovary, diameters of 50 oocytes were measured under a compound microscope, and mean oocyte diameter calculated. Since oocytes varied in size and shape, they were measured randomly, following techniques of Clark (1934) and Cummings (1961). Ovarian developmental stages were formulated according to gross cytology and other characteristics of whole eggs from ovarian smears following King (1948) and Cummings (1961). The following criteria were used in defining developmental stages: mean oocyte diameter, granulation of cytoplasm, visibility of nucleus, presence or absence of cytoplasmic peripheral bodies, and ovary color. Histological preparations were made of selected ovaries to determine if peripheral bodies were present in the cytoplasm. These ovaries were dehydrated in Technicon S-29, embedded in paraffin, sectioned at 8 μ and stained with Papanicolaou Hematoxylin (Harris)—Eosin Y.

Size of males at sexual maturity was estimated using fusion of petasmal endopods as the criterion following Eldred (1958) and Pérez Farfante (1969). Size of females at sexual maturity was estimated through examination of ovarian development.

Diet and Feeding Habits. Pyloric stomach contents of 130 rock shrimp (13.1 to 33.2 mm CL) were examined. Included were 30 individuals collected in October and 20 each from July, September, November, and January, all from regular (nighttime) cruises. In addition, 20 shrimp collected on post-cruises during daylight hours were analyzed. Food items were identified and classified as predominant or residual in stomach contents, following Hall (1962). Predominant items were those which clearly composed most remains in the stomach exclusive of unidentifiable organic material and sediment. Residual items were identifiable fragments occurring in small or trace quantities.

Statistical Analysis. Following logarithmic transformation of data, linear regression of total weight (TW) on carapace length (CL) was made for 300 randomly selected shrimp of each sex; sizes ranged from 9.4 to 36.5 mm CL. Analysis of covariance (Snedecor and Cochran, 1967: 432) was used to test for sexual dimorphism in the length-weight relationship. Regression of carapace length on total length (TL) was calculated for 100 specimens of each sex (7.9 to 30.5 mm CL). Test plotting of CL-TL data revealed a linear relationship, hence no transformation of the data was made. A t-test (Steele and Torrie, 1960:173) was used to test for homogeneity of slopes. For both the CL-TW and CL-TL analyses, goodness of fit of regression lines was determined by analysis of variance (Sokal and Rohlf, 1969: 420).

Sex ratio was analyzed using the G-statistic, a replicated goodness of fit test (Sokal and Rohlf, 1969:575). All samples of 30 or more individuals were used in the calculations. The null hypothesis that the sex ratio in the population is 1:1 was tested.

SYSTEMATICS

Sicyonia brevirostris Stimpson, 1871

Figure 3

Rock shrimp, red shrimp, coral shrimp, ridgeback, Japanese shrimp

Sicyona cristata de Saussure, 1857, p. 306 [erroneous spelling of *Sicyonia*; not *Sicyonia cristata* de Haan, 1850].

Sicyonia cristata de Saussure, 1858, p. 55, p. III, fig. 25 [not *S. cristata* de Haan, 1850].

Sicyonia brevirostris Stimpson, 1871, p. 132 [*nomen substitutum*]; Smith, 1885, p. 80; Faxon, 1896, p. 162; Kingsley, 1899, p. 719; Milne Edwards and Bouvier, 1909, pp. 245-250, figs. 72-83, pl. VII, figs. 1-16; de Man, 1911, p. 10 [listed]; Hay and Shore, 1918, pp. 379-380, pl. XXV, fig. 4; Broad, 1950, pp. 21, 24; Pérez Farfante, 1954, p. 31; Hildebrand, 1954, pp. 268-270, 325; Voss, 1955, p. 192; Wass, 1955, p. 143; Menzel, 1956, p. 41; Ingle, 1956, p. 42 [?part]; Springer and Bullis, 1956, p. 10 [listed]; Lunz, 1957, pp. 3-10; Eldred, 1959, p. 5; Eldred and Hutton, 1960, p. 112, fig. 14; Hulings, 1961, pp. 217, 219; Renfro and Brushner, 1963, p. 15; Joyce, 1965, pp. 164-165, 190, 192; Eldred et al., 1965, p. 32 [?larvae]; Williams, 1965, pp. 35-36, fig. 25; Bullis and Thompson, 1965, p. 7 [listed]; Cook and Murphy, 1965, pp. 109-127 [larval development]; Rouse, 1969, p. 136 [larvae and juveniles].

Eusicyonia edwardsi: Hay and Shore, 1918, pl. XXV, fig. 2 [not *E. edwardsi* Miers, 1881].

Eusicyonia brevirostris: Burkenroad, 1934a, pp. 73, 83-86; Burkenroad, 1934b, p. 117; Burkenroad, 1939, p. 57; Anderson and Lindner, 1945, p. 317; Lunz, 1945, pp. 4, 6-7, 11, fig. 3; Anderson, 1956, p. 2; Bullis and Rathjen, 1959, pp. 19-20.

Diagnosis. Antennal angle armed with moderate, acute, buttressed spine; ischium of first pereopods unarmed; postrostral carina with three, generally four teeth, three large, and posterior to level of hepatic spine.

Description. Carapace pubescent; integument firm. Rostrum not overreaching antennular peduncle, shorter or longer than cornea, tapering distally, horizontal or elevated to as great as 85°; dorsal margin armed with two, occasionally three, subequal teeth excluding tip; tip bifid or trifid, ventral tooth equal to or longer than dorsal tooth, variously curved dorsally, small node often present between dorsal and ventral teeth in bifid condition; ventral margin with proximal one-half setose; conspicuous ridge parallel to ventral border, converging with orbital margin. Postrostral carina high, armed with three keel-like, anteriorly-directed teeth posterior to level of hepatic spine, smaller tooth anterior to level of hepatic spine. Antennal spine moderate, acute, buttressed. Hepatic region swollen, with well-developed, acute spine angled anterodorsally. Gastric and hepatic regions separated by shallow sulcus continuing to base of rostrum; hepatic region bordered ventrally by distinct narrow ridge.

Abdominal somites densely tuberculate, deeply sculptured, pubescent. Abdomen with high mesial carina cleft posteriorly on first five somites; posterodorsal angle of tergum produced into obtuse tooth on somites two through four, acute tooth on fifth. Carina of somite one produced into large, obtuse, anteriorly-directed tooth; conspicuous tooth on posterior margins of last two somites. Ventral margins of pleura bordered by smooth, narrow ridge, fringed with long setae. Pleura of first three abdominal somites broadly rounded posteriorly; anteroventral angle of each armed with curved spine directed anterodorsally. Anteroventral angle of pleuron of fourth somite with prominent, curved spine directed anterolaterally; posteroventral angle with small, acute, posteriorly-directed spine. Somites five and six broadly rounded anteriorly; posterolateral angle armed with acute posteriorly-directed tooth. Posterior margin of first three somites and anterior margin of first somite slightly concave; deep V-shaped indentation near midpoint of posterior margin of pleura of somites four and five. Somite six with pronounced angular projection on posterior margin near midpoint. Somite one traversed by deep, anteromedian pleural groove terminating dorsally at dorsal concavity of tergal margin; long, well-defined posteromedian groove continued to dorsum of tergum; posterior tergal groove shallow, often obscure; posterior pleural groove shallow. Somites two and three each marked with deep anteromedian and posteromedian pleural grooves extending

far dorsally on tergum; anterior and posterior tergal grooves well defined; posterior pleural groove shallow. Fourth and fifth somites traversed by anterior tergal groove terminating near midpoint; posterior tergal groove long, curving anteriorly near ventral margin of pleuron on somite four only. Somite six with shallow, short posterior pleural groove and broad longitudinal sulcus.

Telson long, tapering to strong point, flanked by pair of short, often obsolescent, subterminal spines; dorsal and lateral margins each with distinct longitudinal sulcus.

Eyes subglobular, large; cornea well-pigmented, width at least 0.17 times carapace length.

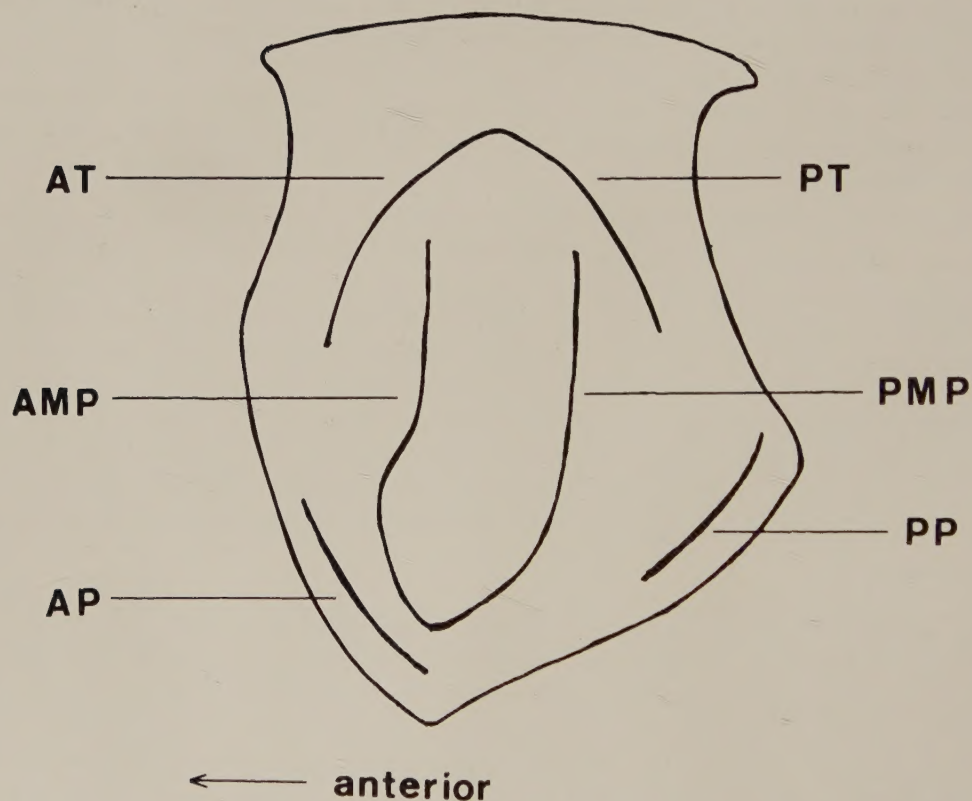


Figure 2. Schematic *Sicyonia* abdominal somite (lateral view) showing all grooves: AT, anterior tergal groove; AMP, anteromedian pleural groove; AP, anterior pleural groove; PT, posterior tergal groove; PMP, posteromedian pleural groove; PP, posterior pleural groove.

Ophthalmic somite with setose, median stylet.

Stylocerite with dorsal row of setae along lateral margin, terminating in slender tooth. Basal segment of antennular peduncle with large distolateral spine reaching to distal one-fourth of second segment. Second antennular segment slightly longer than narrower third segment. Antennular flagella short, not exceeding first segment of peduncle, sparsely setose; median flagellum about two-thirds length of lateral flagellum, tapering to fine point; lateral flagellum more robust, swollen.

Scaphocerite about three-fifths broad as long, reaching to or slightly beyond antennular peduncle; lateral margin noticeably concave, terminating in slender spine slightly overreaching distal margin of lamella; entire medial margin of lamella fringed with long, closely-set setae. Basicerite with stout ventral tooth. Carpocerite long, subcylindrical. Antennal flagella about twice postorbital carapace length, distal two-thirds densely setose on lateral and medial borders.

Third maxillipeds robust, overreaching carpocerite by about length of dactyl, densely setose.

First pair of pereiopods short, extending to about distal margin of carpus of third maxillipeds. Carpus slightly longer than merus, about 1.3 times length of unarmed ischium.

Second pair of pereiopods longer than first, reaching to about distal margin of propodus of third maxillipeds. Carpus long, about 1.2 times length of merus; latter slightly longer than ischium.

Third pair of pereiopods longer than second pair, overreaching third maxillipeds by length of dactyls. Carpus long, about 1.5 times length of merus, latter slightly longer than ischium.

Fourth and fifth pairs of pereiopods similar, fifth longer than fourth by at least length of dactyl. Dactyls as long as or slightly longer than propodus, flattened, apex acute.

Thelycum composed of anteromesial process separated by transverse groove from posterior plate. Mesial process arising on thirteenth somite as broadly concave, subtriangular plate, projecting anteriorly as slender spine to about level of basis of second pereiopods, strongly excavated posteromesially. Posterior margin of mesial process bilobed, hinged, covering opening of seminal receptacles, concave mesially, elevated to form anterior lip of transverse groove. Posterior plate strongly excavated mesially; transverse ridge at posterior margin of excavation; anterior margin produced laterally as large, angular lobe, mesially as large, obtuse lobe; anterior margin elevated, forming posterior lip of transverse groove; oval seminal receptacles evident beneath integument of anterolateral lobes.

Anteromesial process in males similar to that of females but lacking posterior flap and transverse groove, furnished with numerous large setae. Males with transverse ridge overlying juncture of thirteenth and fourteenth sternites; posterior margin slightly sinuous.

Ventral lobules of petasma gaping proximally; distomedial angle a broadly rounded, elevated process; distolateral angle with stout, laterally-directed tooth, tip curved posteriorly. Distomesial angle of dorsal lobule with stout, dorsally-curved spine.

Appendix masculina a cup-shaped bud with lip as angular projection medially. Endopod of second pleopod an obtuse lamina fringed with stout setae, lateral margin crenate.

Sternites of first five abdominal somites armed with robust mesial spine directed somewhat

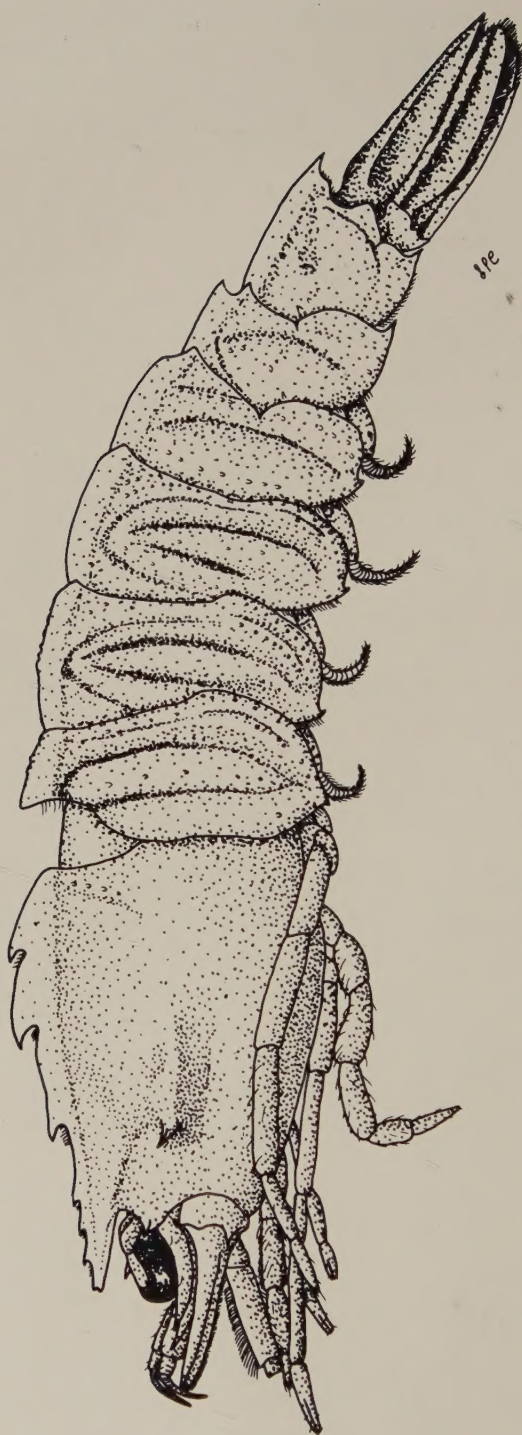


Figure 3. *Sicyonia brevirostris* male, 23.3 mm CL, FSBC I 7554.

anteriorly on first three sternites, curved slightly posteriorly on fourth sternite, and projecting posteriorly on fifth sternite.

Basal segment of uropods with small posteroventral tooth. Uropodal rami elongate, suboval, each with two longitudinal, submedian ridges, margins fringed with long, closely-set setae. Exopod with acute tooth on posterolateral margin.

Color. The color of *Sicyonia brevirostris* in life from the northern Gulf of Mexico was described by Burkenroad (1939) as follows: "Dorsum brown; sides white; belly pink. In detail, the ventral edge of the carapace and antennal scales, pleopods and inner ventral edge of uropods are rose-red. The telson, inner dorsal edge of uropods, pleonic sternites and middle of sides of pleon (between the dorsal brown and ventral white) are washed with pink. The dorsal teeth of the carapace, the posterior end of the dorsal ridge of each pleonic somite, and the sides of carapace and pleon are white. The dorsal ridges of carapace and pleon are chiefly mahogany, the dorsum otherwise olive-brown. The legs are banded with violet or red and white; the antennal flagella are basally mauve, deep lake in the middle, white at tip." Project Hourglass and other eastern Gulf of Mexico material also display this general color pattern. Williams (1965) gave a different color pattern for the dorsum of North Carolina *S. brevirostris*. He states: "Ground color off-white to light pink, pubescence grayish to grayish yellow; dorsal carina barred with white." In freshly preserved specimens from the Yucatan shelf, the dorsal portion of the body is more reddish, and the species is called "red shrimp" by some fishermen. Color of appendages and ventral portion of both Yucatan and North Carolina shrimp is similar to that of northern and eastern Gulf material.

The mottled brownish dorsum of *S. brevirostris* probably serves as camouflage. Color changes in the dorsum with locality may reflect changes in substrate color, texture, or other characteristics of the habitat. The brightly colored appendages and ventral portion of the body may have some function in social behavior, possibly mating.

Morphological Variation. Observed morphological variation in Hourglass specimens is similar to that of other populations of *Sicyonia brevirostris* reported by Burkenroad (1934a), Lunz (1945) and Williams (1965). Burkenroad found the rostrum elevated from 5 to 45° in material from the Bahamas, North Carolina, and the Florida Straits. He considered Milne Edwards and Bouvier (1909) correct in assuming elevation and relative rostral length decrease irregularly with increasing body size.

In Hourglass material, angle of rostral elevation ranged from 0 to 85° and appeared inversely proportional to size in both sexes. A regression of angle of rostral elevation on carapace length was computed, but variation in rostral angle attributable to variation in CL was too large to make the analysis useful. Juveniles generally had a rostral angle greater than 20°. Rostral length was more variable than angle of elevation and was not sexually dimorphic.

Milne Edwards and Bouvier (1909) suggested that the rostral tip changed in form with growth, but this was not found in the present study. The tip of the rostrum in Hourglass specimens has three basic forms, two bifid and one trifid (Figure 4a,b,c). The trifid tip is comprised of three subequal teeth. The bifid conditions include one form with the ventral tooth advanced anteriorly beyond the dorsal tooth, and a second form with the dorsal and ventral teeth subequal, often with a small, intercalated node. The latter bifid form appeared in approximately 72% of Hourglass rock shrimp, while the other bifid and trifid forms were present in 10% and 18% of the shrimp. Different forms of the rostral tip were randomly distributed with respect to size and sex. Burkenroad (1934b) also found no relationship between size and rostral tip morphology, although he examined only a few specimens.

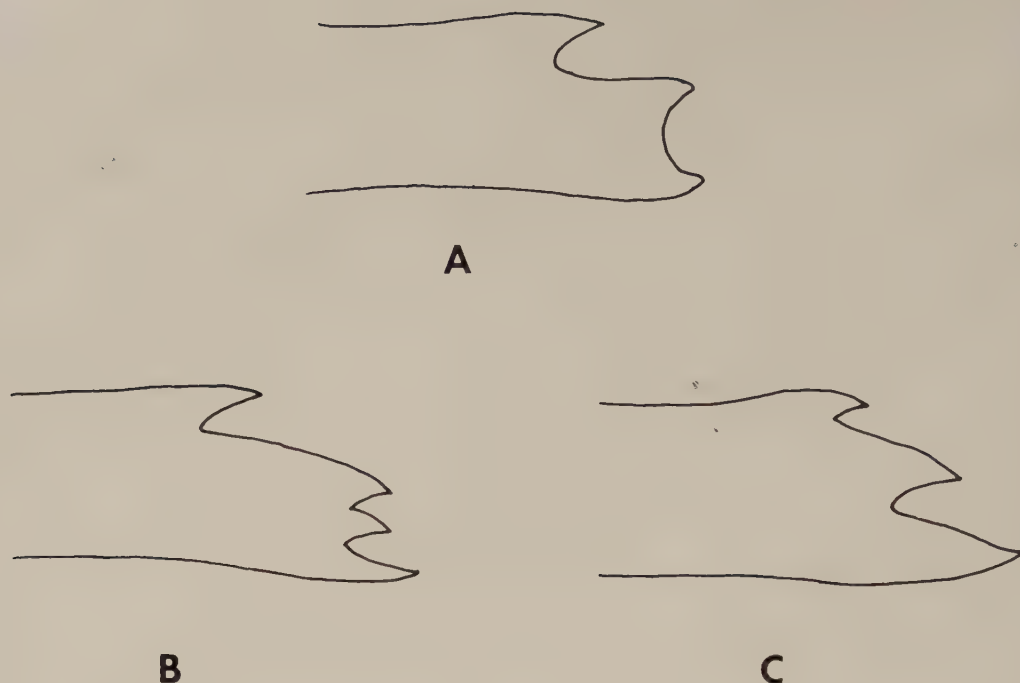


Figure 4. Forms of the rostral tip of *Sicyonia brevirostris*: A, bifid, dorsal and ventral teeth equal; B, trifid; C, bifid, ventral tooth produced beyond dorsal tooth.

Williams (1965) noted that the anterior tooth on the postrostral carina may be located either anterior or posterior to the level of the posterior margin of the orbit. In Hourglass material, placement of teeth on the rostrum and postrostral carina was rather consistent in that most specimens had a dentition formula of 4+2; rarely was the 3+3 form encountered, usually in juveniles.

Burkenroad (1934b) considered the grooves on abdominal somites the best specific character in *Sicyonia*. Likewise, the grooves of *S. brevirostris* are consistent, although they are shallow in small specimens. Spines on the ventral margin of pleura become more distinct with age, being only tubercles in small juveniles.

DISTRIBUTION

Geographic. *Sicyonia brevirostris* occurs along the Atlantic coast of the United States from off Norfolk, Virginia, southward to the Florida Keys (Broad, 1950; Anderson, 1956; Lunz, 1957; Bullis and Rathjen, 1959; Williams, 1965), in the Bahamas (Burkenroad, 1934b), and along the southern coast of Cuba (de Saussure, 1858; Pérez Farfante, 1954). It has centers of abundance off Cape Lookout, North Carolina and along the east coast of Florida north of Palm Beach (unpublished data, National Marine Fisheries Service; Bullis and Rathjen, 1959). In the Gulf of Mexico, *S. brevirostris* ranges from the Dry Tortugas along the entire Gulf coast of the United States, with dense populations occurring off Louisiana (Renfro and Brusher, 1963) and off Cape San Blas, Florida (Ingle, 1956). It has not yet been reported from the eastern shelf of Mexico. The species is common on the Campeche Banks (Hildebrand, 1954, 1955) and is very abundant on the Yucatan shelf in the vicinity of Cabo Catoche, but apparently does not occur south of this point.

Sicyonia brevirostris is known from the eastern Pacific by a single specimen collected in the Gulf of Tehuantepec, Mexico during the 1926 voyage of the R/V *Pawnee*. We concur with Burkenroad (1934a) that it is identical in external morphology to other representatives of this species and is by this criterion conspecific with western Atlantic *S. brevirostris*. Attempts to obtain additional eastern Pacific material were unsuccessful.

The eastern Pacific specimen possibly represents a relict population once continuous with western Atlantic populations through the Atlanto-Pacific Straits during the Tertiary (Schuchert, 1935; Ekman, 1953). Burkenroad (1939) presented a similar explanation for the distributional pattern of the littoral Penaeinae and Sicyoninae. Morphological similarity among American *S. brevirostris* suggests little differentiation since the once continuous Atlanto-Pacific populations became isolated after the Pliocene emergence of the central American land bridge.

Bathymetric. *Sicyonia brevirostris* has been taken from shallow water to depths of 329 m (Williams, 1965) in various parts of its range, with densest populations located between 18 and 73 m. Unpublished data on *S. brevirostris* collected by the R/V *Oregon* on the east Florida shelf show largest catches in depths of 46 to 73 m; Lunz (1957) had highest yields in 64 to 73 m off South Carolina. Relatively large catches of rock shrimp were reported by Bullis and Rathjen (1959) in 40 and 42 m off northeast Florida and in 46 m southeast of Cape Lookout, North Carolina. Joyce (1965) also reported large catches off Cape Canaveral in about 21 m. Off Cape San Blas, Florida, *S. brevirostris* is most common in depths of 18 to 27 m. Renfro and Brusher (1963) recorded maximum catches between 27 and 64 m off Louisiana. Hildebrand (1954, 1955) found rock shrimp most abundant in 11 to 18 m on the Campeche Banks and in depths of 22 to 37 m and 67 to 82 m on the Texas brown shrimp grounds. Shrimpers have reported large catches off Isla Contoy on the Yucatan shelf at depths of 27 to 73 m.

Hourglass collections indicated very few *S. brevirostris* at 6 and 18 m stations. Population density was greatest (and almost equal) at Stations C and K (37 m) (Table 2) and was approximately 3.5 times more abundant on the north transect at 55 and 73 m stations.

Several environmental factors (e.g., temperature, salinity, turbidity, and substrate) may be correlated with the observed distribution pattern. Although discussed separately, these parameters probably act synergistically in determining bathymetric distribution, and no single parameter can be designated as a principal limiting factor.

Rock shrimp distribution seems to be related to the types of overlying water. On the central west Florida shelf at least two distinct water masses are apparent: 1) an inshore "green" or coastal water mass, and 2) an offshore "blue" or shelf water mass. Coastal water, present at 6 and 18 m stations, extends from the beach to approximately 42 to 50 km offshore. Typically, coastal water is more turbid (mean Secchi disk reading at Station B = 13 m) and undergoes greater fluctuations in temperature and salinity than shelf water. Shelf water, distinctly blue, begins somewhere between 18 and 37 m stations and extends seaward beyond 73 m stations. In this water mass, salinity fluctuates relatively little, temperature range is much narrower, and turbidity is much lower (mean Secchi disk reading at Station C = 22 m) than in coastal water. In general, the shelf water mass constitutes a relatively more stable environment than does the coastal water mass.

The relationship between water mass and shrimp abundance is not known, but may involve the physiological response of *S. brevirostris* (as larvae, juveniles, or adults) to salinity and temperature extremes, and light penetration; competition and availability of food may also be important factors.

Sicyonia brevirostris is found most frequently on certain types of substrate. In general, this species inhabits environments with terrigenous and biogenic sand sediments; it occurs only sporadically on mud bottoms. Similar relationships between distribution and sediment type have been demonstrated for other western Atlantic penaeids in the field and in laboratory experiments (Hildebrand, 1954, 1955; Williams, 1955, 1958; Pérez Farfante, 1969).

On the Yucatan shelf *S. brevirostris* is most plentiful on sediments composed of biogenic sand mixed with shell fragments. In the Gulf of Campeche this shrimp is also abundant on white sand-shell substrates (Hildebrand, 1954). In the northwestern Gulf of Mexico, Hildebrand (1955) reported the species as relatively scarce on mud bottoms of brown shrimp grounds and suggested that specimens collected were strays from areas of hard sand or from snapper banks. *S. brevirostris* is quite abundant on terrigenous sand sediments off Cape San Blas in the northeastern Gulf and off the east coast of Florida. Lunz (1957) called *S. brevirostris* the "coral shrimp" because it was occasionally taken from coral banks off South Carolina.

On the central west Florida shelf, the portion of the sea floor explored during Project Hourglass is composed of two distinct sediment types: 1) terrigenous quartz-sand sediments mixed with mollusk shell fragments at coastal stations (A,B,I,J), and 2) biogenic shell and algal-sand sediments at shelf stations (C,D,E,K,L,M) (Gould and Stewart, 1955; Joyce and Williams, 1969). A shift from terrigenous to biogenic sediments is accompanied by a transition from coastal to shelf water. *S. brevirostris* were rarely collected at coastal stations, whereas the population attained maximum density (Table 2) on biogenic sediments at shelf stations. Rock shrimp were most abundant at Stations C and K (37 m) where relatively extensive areas of smooth bottom between limestone outcroppings are composed of crushed shell-sand and other organically derived calcium particles (e.g., *Lithothamnion*) covered by a thin veneer of white silt (Joyce and Williams, 1969). The brown alga, *Sporochnus*, is very common in the area along with large loggerhead and smaller sponges. Living *Lithothamnion* was occasionally taken in large quantities at Station K.

Eldred (1959) and Joyce (1965) concluded that *S. brevirostris* is not dependent on estuarine nursery grounds during its life cycle. The species has been reported from estuaries only by Rouse (1969) who found a "few larvae and small juveniles" in the Chatham River, Florida, at a salinity of 24 o/oo. However, it is possible that this material pertained to other species of *Sicyonia*. The occurrence of rock shrimp primarily at shelf stations during Project Hourglass also suggests that this shrimp does not occupy estuaries.

SEASONAL ABUNDANCE

Population abundance of *Sicyonia brevirostris* varies seasonally. Hildebrand (1955) found it more abundant on the Campeche Banks in February than in July. Catches are greatest in February on the brown shrimp grounds in the northwestern Gulf of Mexico (Hildebrand, 1954). Lunz (1957) found a bimodal seasonal abundance off South Carolina; peaks occurred from September through December and in May. Joyce (1965) obtained highest catches in May and June off northeastern Florida. However, he states "it appears that our offshore stations were too shallow to accurately sample this species." Off Apalachicola, Florida, shrimpers catch the most rock shrimp in summer and early fall.

Fluctuations in total monthly Hourglass catches varied between 1966 and 1967. Combined nighttime trawl catches from comparable months during the last 24 months sampled (Figure 5) suggest rock shrimp were most abundant from July through November. Catches in 1966 reached an

initial peak in July, but a similar increase was not observed in 1967 until August. A second and higher peak of abundance occurred in September 1966 and October 1967; combined catches remained high through November. Population density throughout the study area decreased markedly in December and remained low until summer (Figure 5). However, there were minor increases in March 1966 and January 1967. Total monthly catches were lowest in May, yielding only 13 individuals for both years combined. On the supplementary Hourglass cruises, 132 shrimp were taken in July in contrast to 32 in January (Table 2).

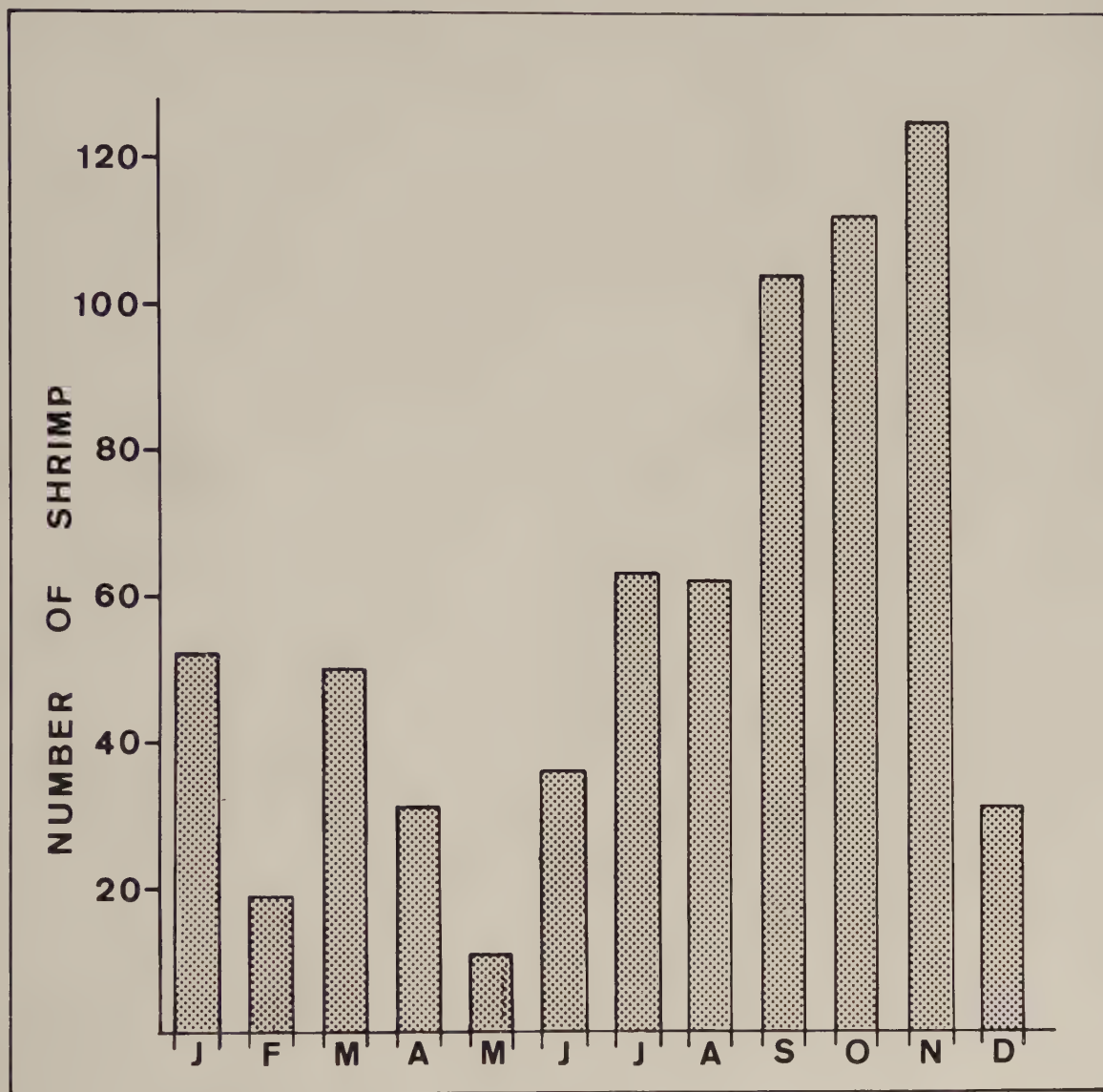


Figure 5. Numbers of shrimp in monthly Hourglass samples (December 1965 through November 1967).

Catches at individual stations throughout the 28 months (Figures 6, 7) varied greatly with no apparent correlation between catches and moon phase, day length, bottom water temperature, or gonadal development. Data are insufficient to show evidence of migration, though such behavior is known to occur among other penaeids (Allen, 1966).

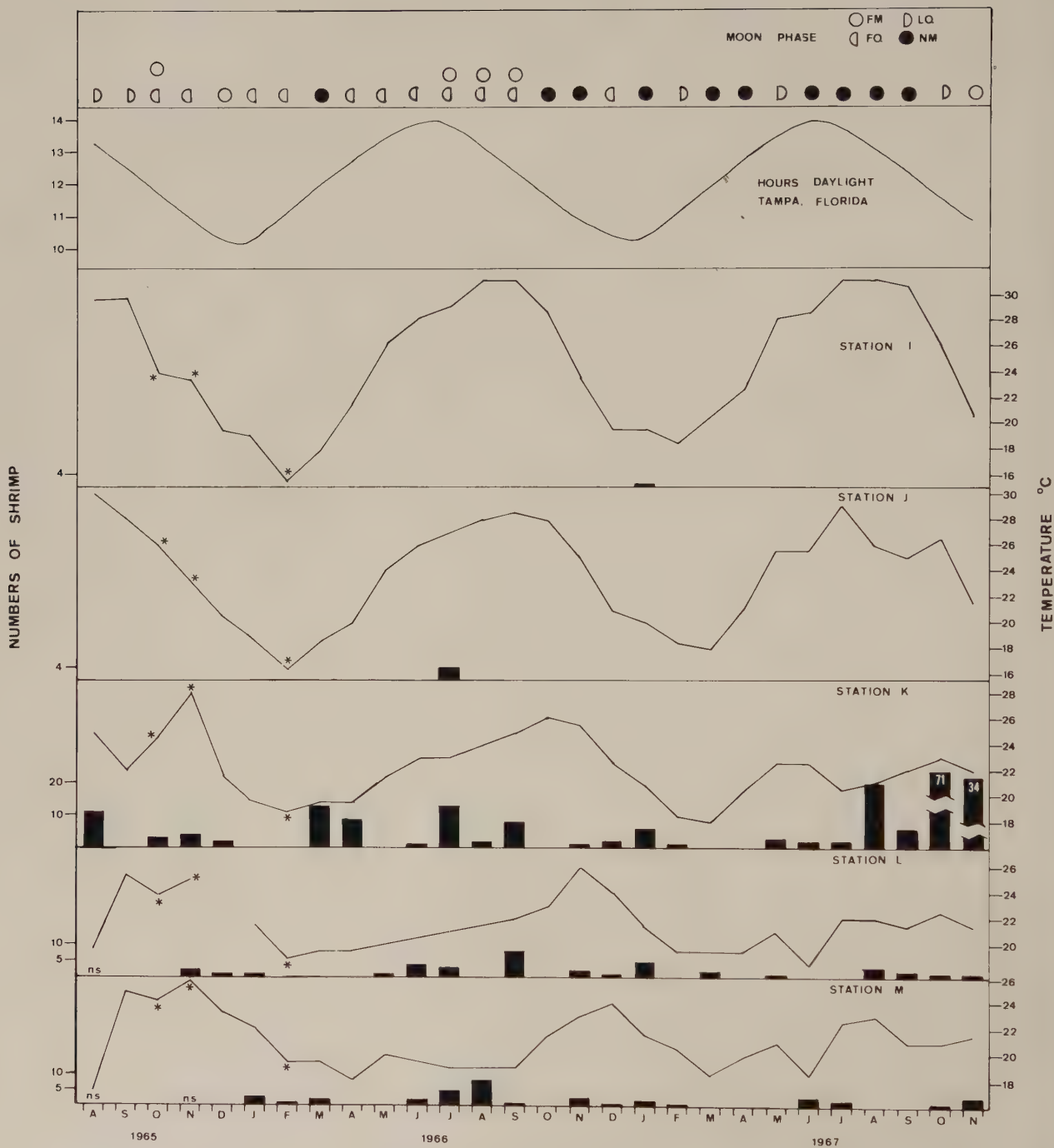


Figure 6. Numbers of shrimp caught in nighttime trynet tows each month, north leg, Stations A-E, in relation to bottom temperature, day length, and moon phase. Asterisks indicate questionable measurements; ns indicates no sample taken.

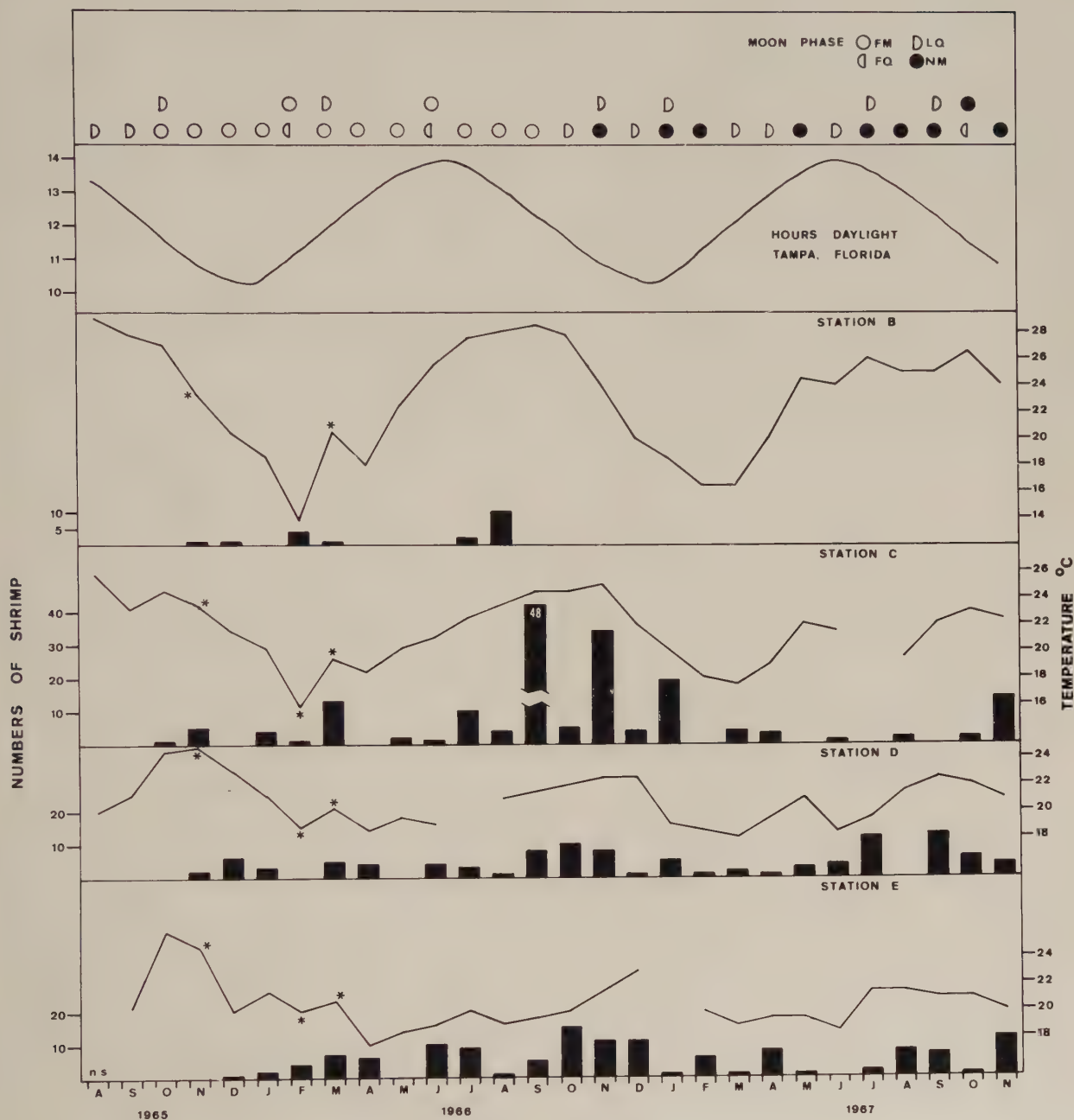


Figure 7. Numbers of shrimp caught in nighttime trynet tows each month, south leg, Stations I-M, in relation to bottom temperature, day length, and moon phase. Asterisks indicate questionable measurements; ns indicates no sample taken.

REPRODUCTION

The reproductive cycle of *Sicyonia brevirostris* probably follows the general pattern described for most other penaeids. At copulation a spermatophore is inserted by the male into seminal receptacles located beneath the posterior plate of the female's thelycum. When the female spawns, eggs are shed free into the water where they are fertilized by sperm concurrently released from seminal receptacles. The embryo hatches from the egg as a nauplius and develops through a series of planktonic larval stages into a postlarva. Postlarvae and early juveniles descend to the bottom and complete their development as benthic animals (Hudinaga, 1942; Lindner and Anderson, 1956; Inversen and Idyll, 1960; Eldred et al., 1961; Joyce, 1965; Kunju, 1967; Rao, 1967; and others). Cook and Murphy (1965) described the larval development of *S. brevirostris* from laboratory studies as follows: five naupliar, three protozoal, four mysis, and at least one postlarval stage occur preceding metamorphosis into a juvenile. The first postlarval stage was reached in 29 days at temperatures varying between 21.0 and 24.5°C and salinities of 24.5 to 27.4 o/oo. They considered *S. brevirostris* unique among littoral penaeids in possessing four instead of three mysis stages.

Ovarian Structure. Ovaries are paired, partly fused, bilaterally symmetrical organs extending from the anterior portion of the cephalothorax to the sixth abdominal somite. They are in the form of anterior, middle, and posterior sac-like lobes (Figure 8). Anterior lobes are slender and closely

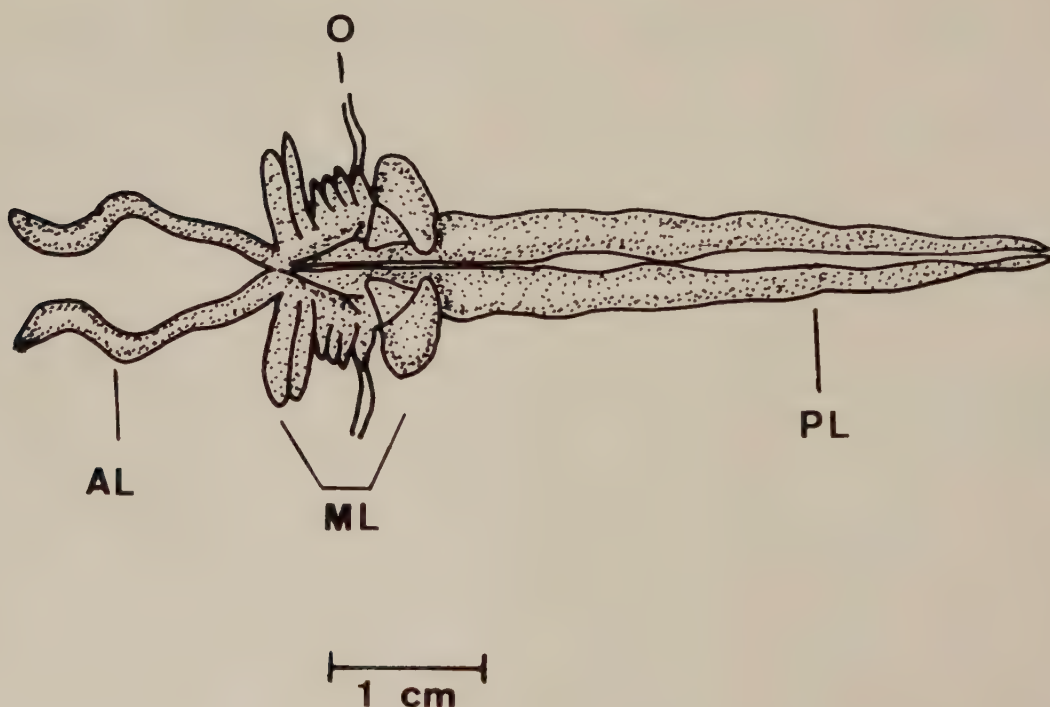


Figure 8. Gross anatomy of ovary (ventral view) of *Sicyonia brevirostris*: AL, anterior lobe; ML, middle lobe; PL, posterior lobe; O, oviduct.

applied to the lateral walls of the pyloric stomach. Middle lobes occupy the posterior half of the cephalothorax and lie between the heart and hepatopancreas. Each middle lobe has two large anterolateral lobules, four smaller lateral lobules, and a large posterolateral lobule with a ventral process arising at its base. Oviducts emerge from the fourth lateral lobules.

Oogenesis. Ovarian development is similar to that of several penaeids (Hudinaga, 1942; King, 1948; Cummings, 1961; Kunju, 1967). Primary oocytes develop from oogonia in zones of proliferation along the floor of the ovary. Oocytes have little or no granulation in the cytoplasm and are basophilic. As development proceeds, oocytes become acidophilic, encased in follicle cells, and many yolk granules appear in the cytoplasm. In ripe oocytes, yolk granules are large and fill most of the cytoplasm which also contains spherical peripheral bodies (Figure 9F). Large numbers of small oocytes are present during all stages of ovarian development.

The spherical peripheral bodies in the cytoplasm are evidently homologous to those reported in oocytes of other penaeids (Hudinaga, 1942; King, 1948; Cummings, 1961; Kunju, 1967). Hudinaga believed these bodies in *Penaeus japonicus* contain a jelly-like substance that is secreted around the outside of the egg immediately after spawning. Histochemical studies on the peripheral bodies of *Penaeus setiferus* by King (1948) gave negative results for lipid and protein, thus the bodies were not believed to contain albuminous yolk. The exact function and composition of peripheral bodies in oocytes of penaeid shrimp remains uncertain.

Developmental Stages. A classification of ovarian developmental stages was used to determine spawning times. The following classification is based on size and gross cytological features of eggs in ovarian smears. Photomicrographs of oocytes in various stages of maturation are presented in Figure 9.

Undeveloped (U) stage: Ovary very small and membranous, transparent or slightly opaque. Oocytes agranulate or slightly granulate, nuclei visible; mean oocyte diameter less than 65 μ .

Early developing (ED) stage: Ovary small, pale green, pale yellow, yellowish-brown, or cream. Oocytes granulate with nuclei visible; mean oocyte diameter 65 to 124 μ .

Developed (D) stage: Ovary medium to large, pale to dark brownish-orange. Oocytes granulate, most with nuclei not visible; mean oocyte diameter 125 to 189 μ .

Ripe (R) stage: Ovary medium to large, dark brownish-orange to dark muddy brown. Oocytes granulate, nuclei not visible; mean oocyte diameter greater than 189 μ . Surface of oocytes appear corrugated due to presence of peripheral bodies in the cytoplasm; peripheral region semi-transparent.

Spent (S) stage: Ovary small to large, often flaccid. Many follicle cells and degenerating oocytes. In preserved material this stage was very difficult to distinguish from the ED-stage.

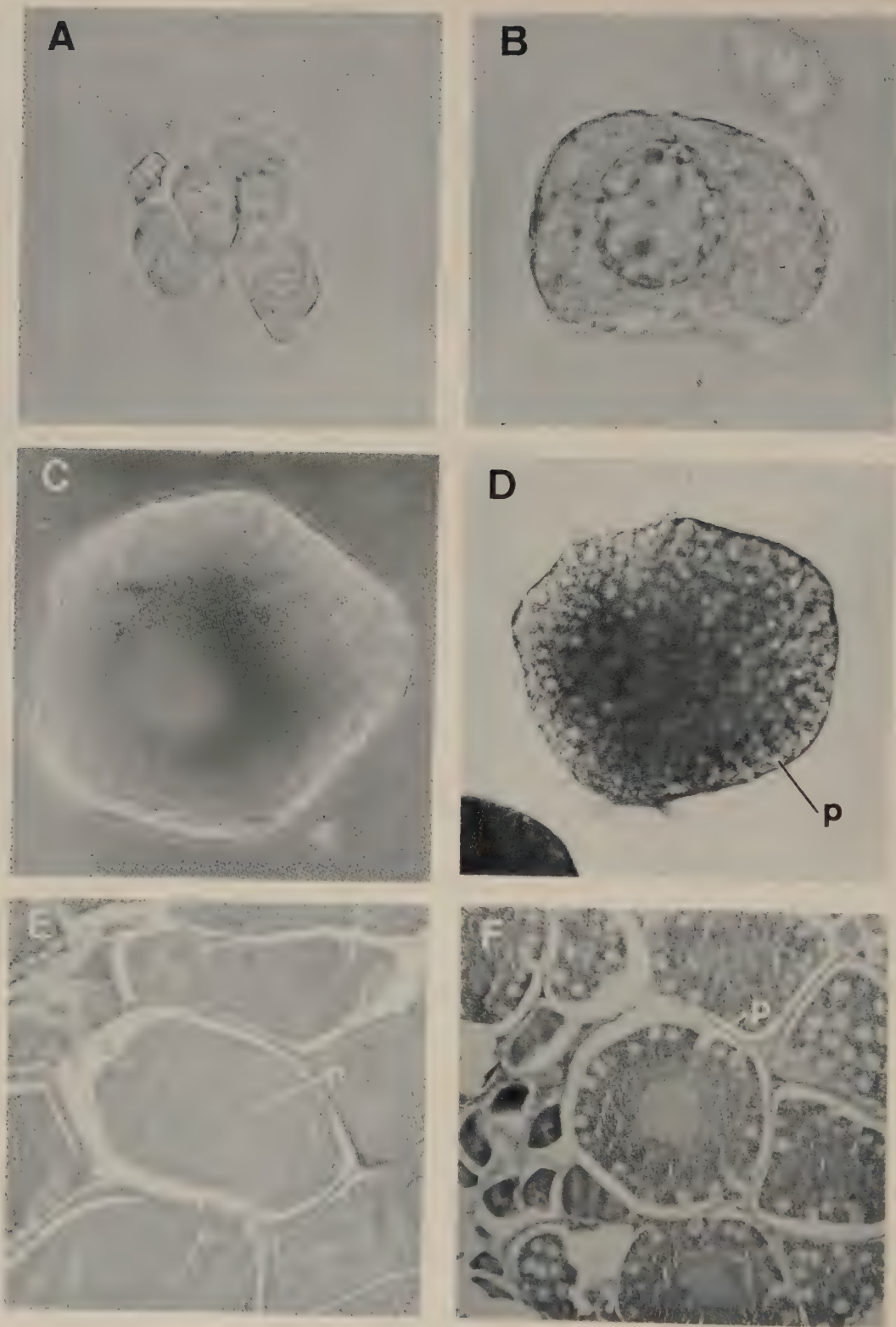


Figure 9. Photomicrographs of *Sicyonia brevirostris* oocytes in various stages of development: A, Undeveloped stage, x430; B, Early Developing stage, x430; C, Developed stage, x150; D, Ripe stage, x150; E, cross section of Developed ovary, x100; F, cross section of Ripe ovary, x100. (n—nucleoli; p—peripheral bodies).

TABLE 3. NUMBERS AND PERCENTAGES OF OVARIAN DEVELOPMENTAL STAGES BY SIZE
(ALL MONTHS COMBINED)

Size class (CL, mm)		Ovarian Developmental Stages										
		Undeveloped (U)		Early Developing (ED)		Developed (D)		Ripe (R)		Spent (S)		Total
	No.	%	No.	%	No.	%	No.	%	No.	%		
3.0-4.9	1	100	---	---	---	---	---	---	---	---	1	
5.0-6.9	3	100	---	---	---	---	---	---	---	---	3	
7.0-8.9	9	100	---	---	---	---	---	---	---	---	9	
9.0-10.9	16	94	1	6	---	---	---	---	---	---	17	
11.0-12.9	31	86	3	8	1	3	1	3	---	---	36	
13.0-14.9	34	77	7	16	2	5	1	2	---	---	44	
15.0-16.9	27	66	11	27	2	5	1	2	---	---	41	
17.0-18.9	7	19	25	68	3	8	1	3	1	3	37	
19.0-20.9	8	23	19	54	5	14	3	9	---	---	35	
21.0-22.9	4	9	21	46	16	35	5	11	---	---	46	
23.0-24.9	5	10	18	36	18	36	8	16	1	2	50	
25.0-26.9	2	3	23	37	27	44	8	13	2	3	62	
27.0-28.9	1	3	7	23	18	60	3	10	1	3	30	
29.0-30.9	---	---	4	16	13	52	6	24	2	8	25	
31.0-32.9	---	---	8	40	7	35	4	20	1	5	20	
33.0-34.9	---	---	1	20	2	40	1	20	1	20	5	
35.0-36.9	---	---	---	---	---	---	---	---	1	100	1	
37.0-38.9	---	---	---	---	1	100	---	---	---	---	1	
Total	148		148		115		42		10		463	

Size at Maturity. The smallest mature female collected was 12.0 mm CL. However, ripe females smaller than 19 mm CL were uncommon (Table 3), indicating that spawning is mainly accomplished by larger individuals.

Ovaries of all females less than 9.0 mm CL were undeveloped. Early developing ovaries first appeared in the 9.0-10.9 mm CL size class. This suggests that up to about 9.0 mm CL ovarian development is probably an ontogenetic process and not a function of time of year. For females greater than 13 mm CL, ovarian development seems less dependent on size and more closely related to season.

Sicyonia brevirostris males become sexually mature at smaller sizes than females. Estimated size at onset of sexual maturity for males was 9.0 mm CL. All males 11 mm CL or greater had a fused petasma and were considered sexually mature. Two males larger (9.2, 10.5 mm CL) than the estimated value had the petasmas unjoined, illustrating the variability of this phenomenon.

Spawning. Because of small sample sizes (N = 4 to 85) in some months, ovarian developmental data from all months of collecting were combined (Table 4); consequently, rigorous statistical analysis of the data was not possible. However, some trends of the reproductive cycle were evident from available information.

TABLE 4. NUMBERS AND PERCENTAGES OF OVARIAN DEVELOPMENTAL STAGES BY MONTH (ALL YEARS COMBINED).

Month	Ovarian Developmental Stages										Total
	Undeveloped (U)		Early Developing (ED)		Developed (D)		Ripe (R)		Spent (S)		
	No.	%	No.	%	No.	%	No.	%	No.	%	
January	6	13.6	15	34.1	16	34.6	7	15.9	1	—	44
February	1	6.6	4	26.6	9	60.0	—	—	1	6.6	15
March	5	26.3	10	52.6	3	15.8	1	5.3	—	—	19
April	5	27.8	6	33.3	3	16.7	3	16.7	1	5.6	18
May	2	50.0	2	50.0	—	—	—	—	—	—	4
June	13	54.2	8	33.3	3	12.5	—	—	—	—	24
July	42	44.7	36	38.3	13	13.8	2	2.1	1	1.1	94
August	14	51.9	9	33.3	3	11.1	1	3.7	—	—	27
September	25	49.0	15	19.4	5	9.8	5	9.8	1	1.9	51
October	11	17.5	19	30.2	24	38.1	8	12.7	1	1.6	63
November	20	23.5	21	24.7	28	32.9	13	15.3	3	3.5	85
December	4	21.1	3	15.8	8	42.1	2	10.5	2	10.5	19
Total	148		148		115		42		10		463

Females with U-stage ovaries were found throughout the year. Percentages of U-stage ovaries were highest from June through September and lowest in December, January, and February. Percentages of ED-stage females were high in all months but December. D-stage females occurred in all months except May; peak numbers occurred in October and November, but percentages were highest from October through February. Relatively few females with R-stage ovaries were collected; these occurred sporadically. Maximum number and percent of R-stage ovaries occurred from October through January.

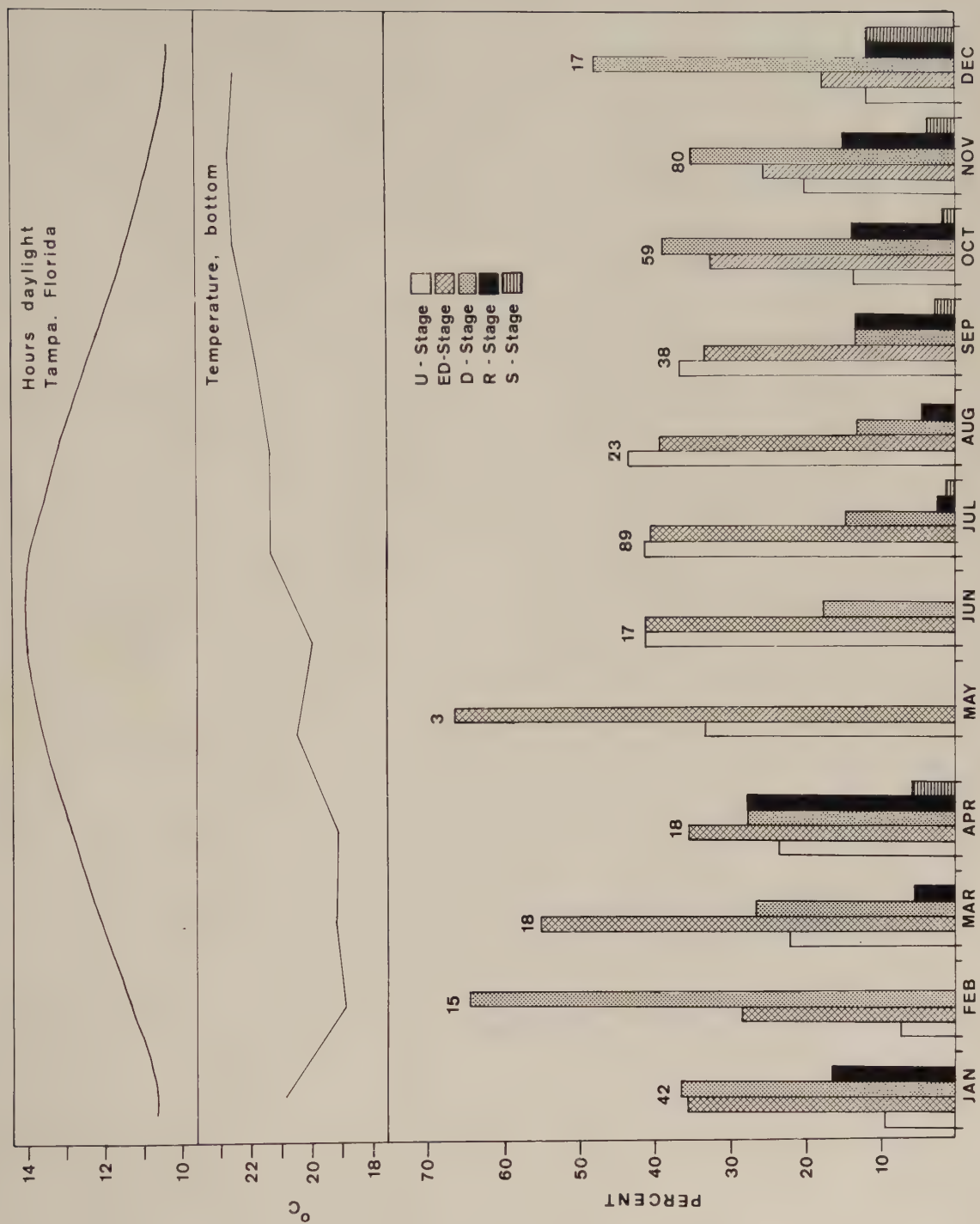


Figure 10. Stages of ovarian development of all ovaries examined in shrimp with carapace length 13 mm or greater (December 1965 through November 1967) compared with mean bottom temperature at offshore stations C-E and K-M, and day length, Tampa, Florida. Numbers at top of bars represent number of females examined.

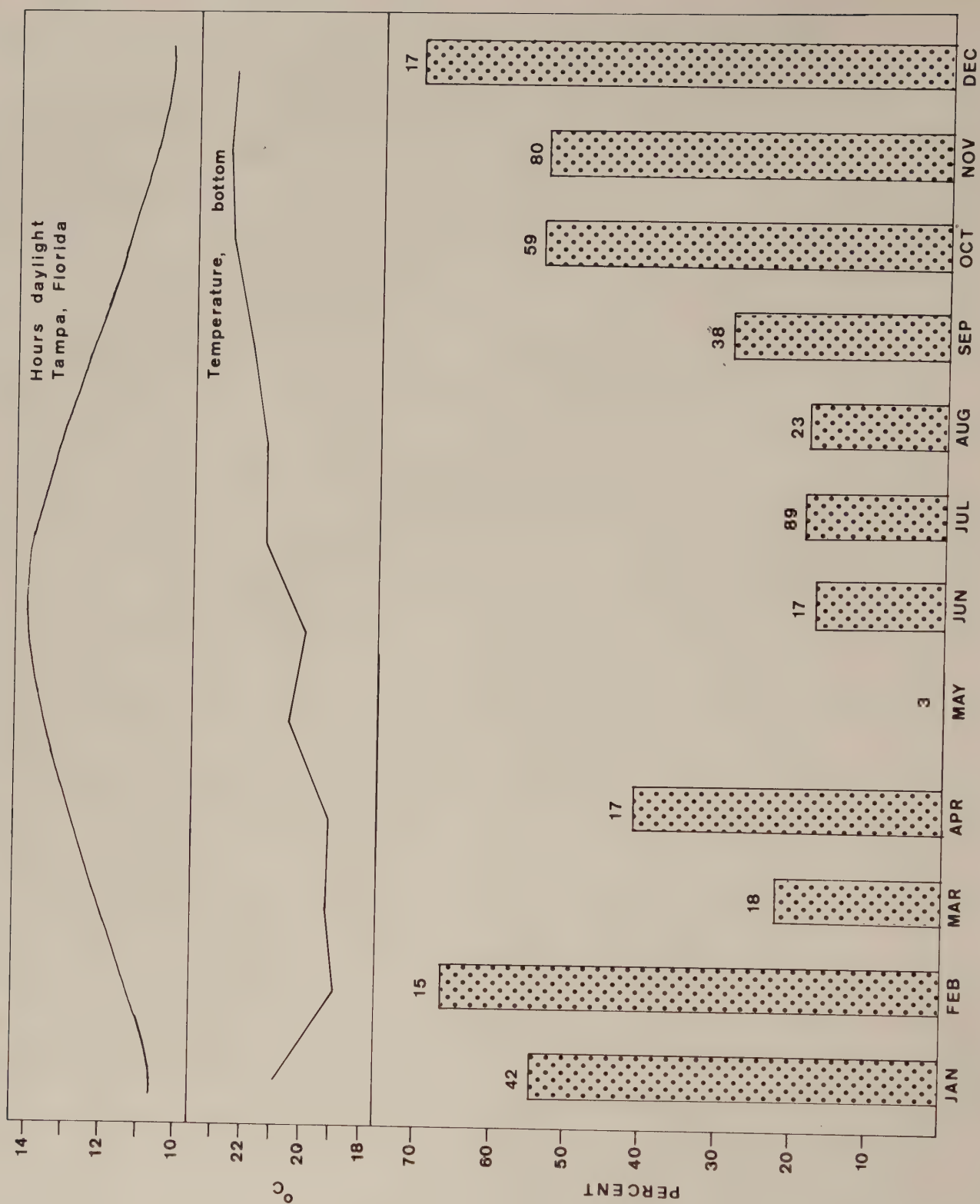


Figure 11. Combined frequencies of D-, R-, and S-stage ovaries in shrimp with carapace length 13 mm or greater (December 1965 through November 1967) compared with mean bottom temperature at offshore stations C-E and K-M, and day length, Tampa, Florida. Numbers at top of bars represent number of females examined.

Apparently the spawning season is protracted, although peaks are discernible. Percentage of D-, R-, and S-stage females in the population was relatively high from October through February (Figures 10, 11), thus suggesting that peak spawning in the study area occurs during these months. However, presence of D-, R-, or S-stage females in all other months but May (which had a small sample size) further suggests some year-round spawning. Yearlong spawning has been reported for several other penaeids, in certain portions of their ranges; these include *Penaeus d. duorarum* (Ingle et al., 1959; Eldred et al., 1961; Cummings, 1961), *P. a. aztecus* (Renfro and Brusher, 1963), *P. stylifera* (Rao, 1967), and *Metapenaeus dobsoni* (Rao, 1967).

Joyce (1965) reported female rock shrimp with mature ovaries off the northeast Florida coast in January. Lunz (1957) collected females with "well developed roe" from September through December and in May off South Carolina. These findings are in general agreement with those reported here.

Ovarian development shows some correlation with decreasing photoperiod (Figures 10, 11). Maximum spawning activity, which apparently takes place from October through February, may be triggered by reduced day length during this time. Moe (1969) found that gonadal activity of red grouper from the west Florida shelf correlated well with photoperiod but was unrelated to temperature changes. Peak spawning period of *S. brevirostris* could not be correlated with either minimum or maximum, increasing or decreasing bottom temperatures (Figures 10, 11). Studies of larval abundance and distribution could more properly delineate the reproductive cycle.

Sex Ratio. Total rock shrimp catch from Project Hourglass consisted of 53.5% (521) females and 46.5% (452) males. This suggested the sex ratio of the population was not 1:1, females being slightly more numerous. To see if this trend was statistically significant, sex ratio data was analyzed using the G-test, a function similar to the Chi Square statistic. Total G-value was not significant at the 5% level (Tables 5,6) and hence the null hypothesis that the sex ratio is 1:1 was not rejected. However, samples from November 1966 and 1967 (Tables 5,6) differed significantly from the 1:1 ratio, females outnumbering males.

TABLE 5. MALES AND FEMALES USED FOR STATISTICAL ANALYSIS OF SEX RATIO.

Sample	Number of females	Number of males	Sum
Jul 1966, Sta. C	32	32	64
Sep 1966, Sta. C	28	20	48
Nov 1966, Sta. C	23	9	32
Jul 1966, Sta. D	24	24	48
Oct 1967, Sta. K	30	41	71
Nov 1967, Sta. K	23	11	34
Total	160	139	299

TABLE 6. SUMMARY OF G-TEST ANALYSIS OF SEX RATIO.

Tests	df	G	Sample	df	G
Pooled	1	1.5076 ns	Jul 1966, Sta. C	1	0.0076 ns
Heterogeneity	5	10.2300 ns	Sep 1966, Sta. C	1	1.3452 ns
Total	6	11.7376 ns	Nov 1966, Sta. C	1	4.3316 *
			Jul 1966, Sta. D	1	0.0032 ns
			Oct 1967, Sta. K	1	1.7184 ns
			Nov 1967, Sta. K	1	4.3316 *

* – significant at the 5% level

ns – not significant

Females became increasingly more numerous than males in larger size categories. Above 26 mm CL, females composed 65% of the total Hourglass catch, but below this size the sex ratio approached unity. Joyce (1965) reported females as more numerous than males above 50 to 59 mm TL. Also, Lunz (1957) found more females than males in the 127 to 152 mm TL category, though the reverse was true in the 51 to 102 mm size range. Apparently more females than males attain larger sizes, which may reflect sexual differences in growth rate or longevity.

SIZE STRUCTURE OF THE POPULATION

Length-frequency data (Figure 12) for *Sicyonia brevirostris* are difficult to interpret because of the extended breeding season and small sample sizes, but some general characteristics of population dynamics are revealed.

Appearance of smaller (CL less than 7.0 mm) individuals in March, May, June, July and November indicates recruitment during these months. Slightly larger individuals (CL less than 11.0 mm) in all months but December further indicate year-round spawning.

No distinct modal progressions reflecting individual or population growth are discernible. Year-round spawning possibly masks modal progressions.

MORPHOMETRIC RELATIONSHIPS

Specimens used in deriving length-weight equations were captured during all months and represent a rough average of all stages of gonadal development, stomach fullness and other variables which might affect the relationship.

Regression equations for calculating log weight (Y) from log carapace length (X) are presented by sex and for both sexes combined in Table 7. Also listed is the percentage of variation in Y attributable to variation in X. These values are derived from analysis of variance of the partitioned

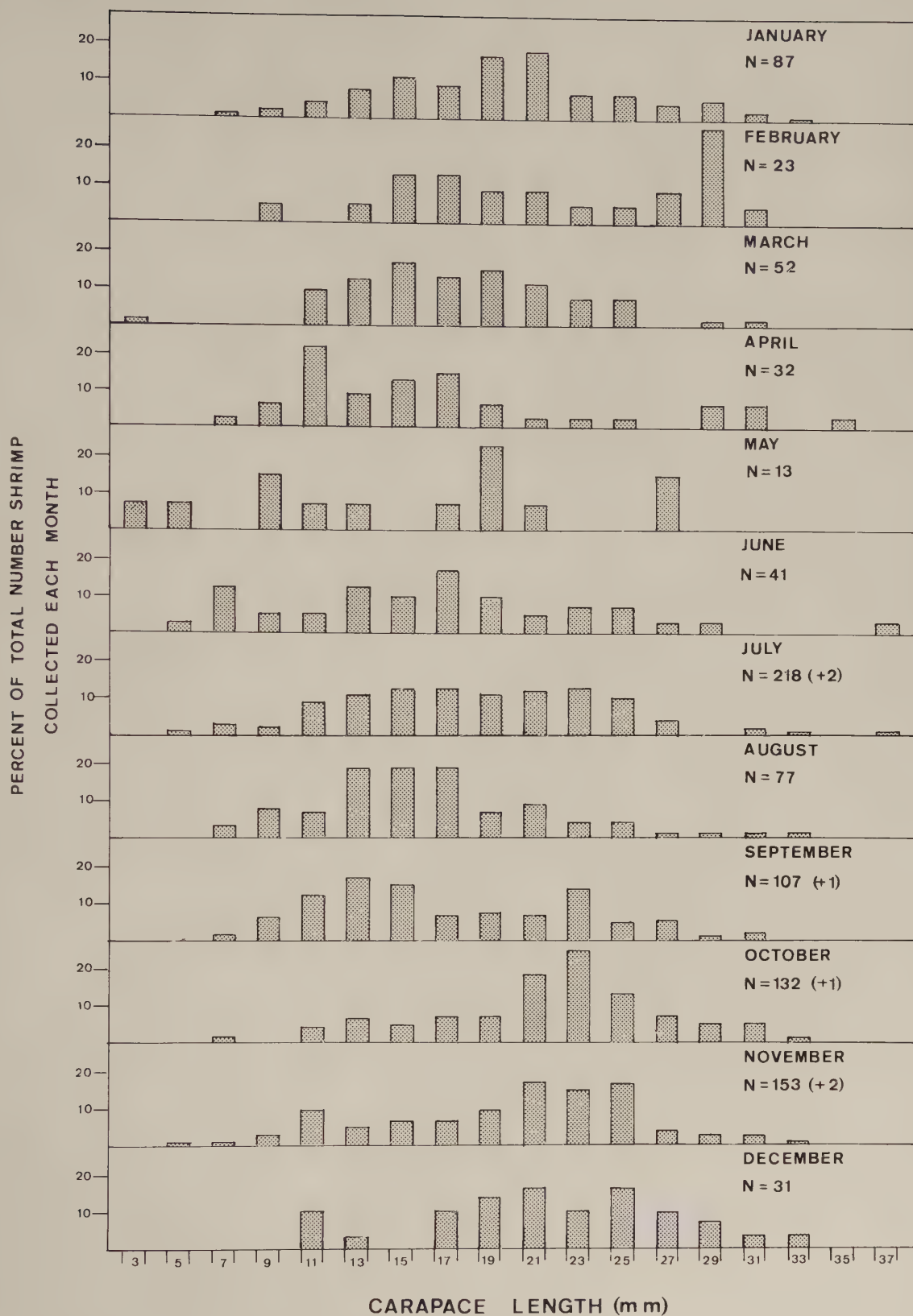


Figure 12. Monthly changes in size structure of the population (all months combined). Numbers in parentheses indicate damaged specimens.

sums of squares from the regression analysis (Sokal and Rohlf, 1969:421) and measure closeness of fit of the data to the regression equation.

Analysis of covariance showed no significant difference at the 5% level between the length-weight relationship of males and females with respect to variance, slope and elevation of the respective regression equations. Percent variation in weight (Y) attributable to variation in carapace length (X) was 95%; hence, the combined equation for estimating total weight from carapace length can be used with confidence.

A t-test revealed a significant difference at the 5% level between slopes of the carapace length-total length equations for males and females; therefore, equations for both sexes could not be combined. In addition, a t-test showed that while the regression equation for males went through the origin, that for females did not. Equations relating carapace length (X) to total length (Y) are:

$$\begin{array}{l} \text{Males} \\ \hat{Y} = 3.7783X \\ \hat{X} = 0.2644Y \end{array}$$

$$\begin{array}{l} \text{Females} \\ \hat{Y} = 4.4503 + 3.4562X \\ \hat{X} = -0.9152 + 0.2847Y \end{array}$$

Percent variation in Y attributable to variation in X is 99% and 98% for males and females.

Kutkuhn (1962) calculated regression equations for predicting "headless" (Y) from "whole" (X) weights of *S. brevirostris* (N = 477), and vice versa. His equations for regression through the origin are:

$$\begin{array}{l} \hat{Y} = 0.601X \\ \hat{X} = 1.659Y \end{array}$$

Sixteen pounds of fresh "whole" rock shrimp collected off Cape Canaveral, Florida produced 9.6 lb of tails and 7.0 lb of shelled meats. This amounts to a 40% weight loss after heading, a 56% loss (from "whole" weight) after shelling, and a 27% loss from tail weight after shelling. In other words, 100 lb of "whole" shrimp will yield approximately 60 lb of tails and 44 lb of shelled meat. One hundred lb of tails will yield about 73 lb of meats. Shrimp were not deveined in this experiment. Lunz (1957) reported a heading loss of 38.5% for rock shrimp collected off South Carolina.

TABLE 7. REGRESSION EQUATIONS FOR ESTIMATING LOG TOTAL WEIGHT (Y) IN GRAMS FROM LOG CARAPACE LENGTH (X) IN MILLIMETERS.

Sex	Sample Size	Equation	Percent Variation in Y Attributable to Variation in X
Female	300	$\log \hat{Y} = -3.2210 + 3.1218 \log X$	96.4
Male	300	$\log \hat{Y} = -3.2301 + 3.1442 \log X$	92.2
Combined	600	$\log \hat{Y} = -3.2192 + 3.1279 \log X$	94.8

DIET AND FEEDING HABITS

Stomach contents were finely triturated, making food items difficult to identify. Unidentifiable organic material, sand, and silt generally composed a large portion of stomach contents. Apparently most organic material in stomachs was not detritus but fragments of animals consumed alive. Relative importance of various food items in the diet is listed in Table 8.

Diet studies on many penaeids have shown that various species may be either omnivores, herbivores, generalized carnivores, or specialized carnivores (Weymouth et al., 1932; Williams, 1955; Eldred et al., 1961; Hall, 1962; Pérez Farfante, 1969). *Sicyonia brevirostris* seems to be a nocturnal, benthic feeding, generalized carnivore as evidenced by 1) ubiquity of empty stomachs (100%) among individuals collected during daylight hours, 2) presence of only benthic species in stomachs, 3) apparent absence of plant matter in the diet, and 4) wide diversity of species consumed. Feeding apparently occurs throughout the year since 80% of the stomachs examined from shrimp taken at night during all seasons were at least 50% full.

TABLE 8. FOOD ITEMS IN THE DIET OF *SICYONIA BREVIROSTRIS*.

Food Items	Predominant		Residual		Total	
	Number	Percent*	Number	Percent*	Number	Percent*
Algae	---	---	3	2.8	3	2.8
Foraminifera	---	---	35	32.7	35	32.7
Porifera (spicules)	1	0.9	4	3.7	5	4.7
Nematoda	---	---	12	11.2	12	11.2
Polychaeta	---	---	4	3.7	4	3.7
Mollusca						
Bivalvia	77	72.0	15	14.0	92	86.0
Gastropoda	8	7.5	48	44.9	56	52.3
Pycnogonida	---	---	8	7.5	8	7.5
Stomatopoda	1	0.9	---	---	1	0.9
Unidentifiable						
Crustacean fragments	3	2.8	17	15.9	20	18.7
Small Crustacea						
Ostracoda	---	---	11	10.3	11	10.3
Amphipoda	3	2.8	7	6.5	10	9.3
Isopoda	---	---	1	0.9	1	0.9
Decapod Crustacea						
Natantia	10	9.4	6	5.6	16	15.0
Anomura	5	4.7	4	3.7	9	8.4
Brachyura	5	4.7	6	5.6	11	10.3
Ectoprocta	1	0.9	6	5.6	7	6.5
Echinoidea	---	---	3	2.8	3	2.8
Pisces	---	---	3	2.8	3	2.8
Empty Stomachs					23	17.7**

*Percent of total stomachs (107) containing food.

**Percent of total stomachs (130) examined.

Small bivalve mollusks and decapod crustaceans are the principal components of the diet; small gastropods and other crustaceans are also important food sources. The most commonly ingested bivalve was *Lucina multilineata*. Two other bivalves, *Gouldia cerina* and *Chlamys benedicti*, and unidentifiable fragments of bivalves were present in stomachs in smaller quantities. Abundance of byssal threads in many stomachs and the fresh condition of shells indicated live bivalves were eaten and that observed shell fragments were not incidentally ingested sediment.

A diverse array of small gastropods was consistently present in stomachs in low quantities. Some of the more common species in the diet of *S. brevirostris* include: *Natica pusilla*, *Olivella* sp., *Vermicularia knorri*, *Balcis* sp., *Rhizorus oxytatus*, *Alvania* sp., *Litiopa melanostoma*, *Compsodrillia eucosmia*, *Turbonilla* sp., *Kurtziella* sp., *Cerodrillia simpsoni*, *Alabina* sp., *Terebra* sp., *Cochlespira radiata*, *Odostomia* sp., *Nassarius* sp., and a vitrinellid. Numerous opercula in stomachs together with shells containing tissue indicate that most gastropods were ingested alive. In addition, some shells containing hermit crabs were eaten.

The most prevalent decapods in rock shrimp stomachs were shrimps of the genera *Leptochela* and *Processa*. Brachyurans were less common in the diet and consisted mainly of spider crabs. Cannibalism probably occurs; *S. brevirostris* fragments were found in two stomachs.

The degree to which feeding in the trynet might have influenced results of stomach contents analysis is not known, but since principal food items, especially mollusks, were seldom present in trynet samples, it is believed that "net feeding" did not appreciably bias the results.

Mandibular structure of *S. brevirostris* is well suited for crushing and grinding food. The mandibles, similar to those of other penaeids (Young, 1959; Boschi and Angelescu, 1962) are large, with well-developed molar processes (Figure 13). The stout, dentiform incisor processes probably mascerate food items before they enter the mouth. Mollusks and crustaceans initially reduced by the mandibles are subsequently triturated by the large, obtuse teeth of the gastric mill.

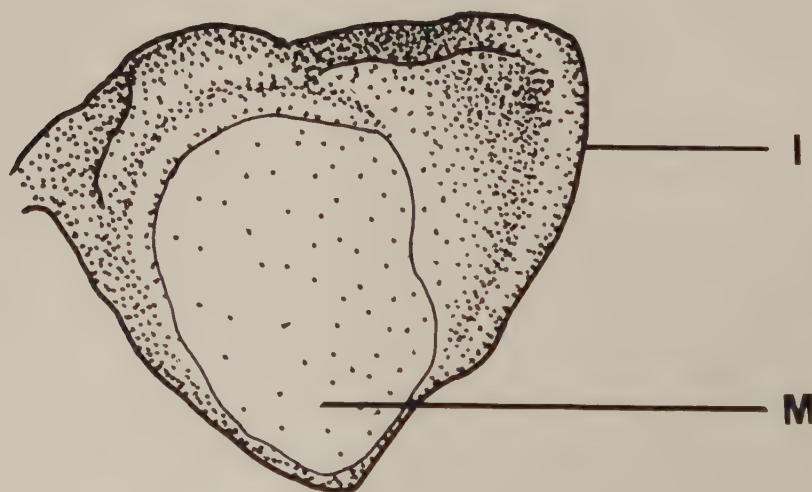


Figure 13. Mesial view of distal portion of left mandible of *Sicyonia brevirostris* (mandibular palp omitted): I, incisor process; M, molar process.

PREDATION

Data from Project Hourglass on predation of *Sicyonia brevirostris* are meager since most records on fish stomach contents refer only to "shrimp," and the diets of other possible predators, e.g., sea stars, have not been examined. Among the material available for study, six rock shrimp ranging in size from 11 to 20 mm CL were present in stomach contents of the flounder *Syacium papillosum* (one shrimp per stomach). Single individuals (13.8 to 25.9 mm CL) were present in stomachs of two *Scorpaena brasiliensis*, one *S. calcarata*, one *S. agassizi*, and one sand perch, *Diplectrum formosum*. The abundant *Syacium papillosum* and *Scorpaena brasiliensis* are mainly crustacean feeders (Topp and Hoff, 1972) and possibly prey more extensively on rock shrimp than is suggested by the above data. Burkenroad (1934a) reported a single rock shrimp from the stomach of a yellowfin grouper, *Mycteroperca venenosa*, collected in the Bahamas, and Wells et al. (1961) listed *S. brevirostris* from among stomach contents of two specimens of the sea star, *Astropecten articulatus*, from off North Carolina. In view of the relative abundance of *S. brevirostris*, their scarcity as food items is enigmatic. It is possible that certain serranids, lutjanids, or other large species could be major predators but, due to their habits, were not adequately sampled.

DIET CYCLE

Catches during daylight hours were significantly lower than those at night (Table 2). Trynet tows at night produced 93.6% and 88.5% of combined day and night catches at Stations C and D. Bottom dredge hauls also contained a higher percentage of the catch at night than during the day. Anderson (1956), Lunz (1957), and Joyce (1965) also noted that *S. brevirostris* catches were greatest at night.

The data strongly suggest that *S. brevirostris* is primarily a nocturnally active shrimp that probably buries into the substrate during the daytime, thereby largely avoiding predators and the trawl. Similar behavior has been reported for commercially important species of *Penaeus* (Springer and Bullis, 1956; Aaron and Wisby, 1964; Fuss and Ogren, 1966; Saloman, 1968; Pérez Farfante, 1969). Results of diet analysis of the present study also suggest that *S. brevirostris* is more active at night.

ECONOMIC POTENTIAL

Commercial concentrations of rock shrimp were not found during Project Hourglass. Since trawling for pink shrimp along the central west coast of Florida is mainly confined to nearshore areas (Joyce and Eldred, 1966), the rock shrimp contributes little to catches of the local fishery.

In other areas of Florida, according to Joyce (1965), Joyce and Eldred (1966), and local shrimp fishermen, populations of economic potential do exist. The most promising locality is off the northeast coast where exploratory trawling by the National Marine Fisheries Service produced catches as high as 100 lb per hour. A small rock shrimp fishery has recently developed off Fort Pierce, and large catches have been reported in waters off Cape Canaveral. Also, off the northwest Florida coast there have been moderately high yields in the vicinity of Cape St. George.

Dense populations of *S. brevirostris* are believed to occur in other areas of the Gulf. Renfro and Brusher (1963) reported large catches in the northwestern Gulf between Galveston, Texas and Cameron, Louisiana and stated "this penaeid may be present in sufficient quantities to support a

commercial fishery." On the Yucatan shelf in the vicinity of Isla Contoy, very large catches have been reported by Florida shrimpers, but a fishery has not yet been established. Scarcity of markets and processing difficulties have hindered development of a rock shrimp fishery. However, recent processing advances and rapidly expanding markets indicate that the rock shrimp will soon become an established commercial marine resource. Additionally, it may provide a supplementary income for the shrimping industry in several localities. Joyce (1965) suggested that trawling for rock shrimp during the off season (January to June) might produce revenue for shrimpers along the northeast Florida coast.

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